

Indian Institute of Technology Kanpur

AE451A

Experiments in Aerospace Engineering - III

Experiment No. 8

Studies on Subsonic jet propagation

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1. Objective

To study the development of velocity profiles in an axisymmetric jet by using a single Pitot tube with traverse mechanism.

2. Introduction and theory

Free turbulence: High-Reynolds-number shear flow in an open ambient fluid, unconfined or uninfluenced by walls. A jet issuing into a still (or moving) stream is a common case of free turbulence. It has a characteristic velocity scale, $U_{max}(x)$ and a characteristic shear-layer width, $b(x)$. Since these flows are free, or unconfined, the pressure is approximately constant throughout the flow, except for (small) turbulent fluctuations within the layer.

Figure 1. shows the details of the initial formation of a jet, assuming a still ambient fluid. The figure is valid only for similar jet and ambient fluids, e.g., air-into-air, not water-into-air. Velocity profiles are shown as thick dark lines across the flow. Typically the jet issues as a nearly at, fully developed turbulent velocity U_{exit} . Mixing layers form the lip of the exit, growing between the still ambient and the nearly inviscid potential core flowing at velocity U_{exit} .

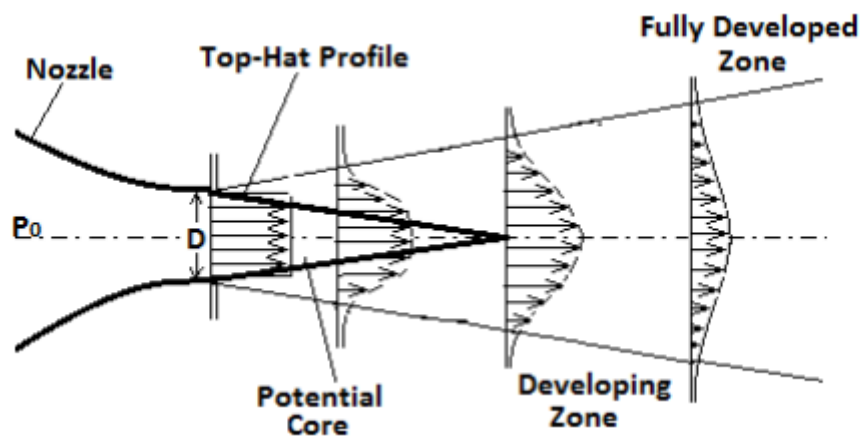


Figure 1. Initial formation of jet

The region where the centre line velocity is equal to the nozzle outlet velocity is called the potential core of the jet. The potential core vanishes quickly, at a distance of about one diameter from the exit, where the velocity profile loses its mixing-layer-at-core shape. Downstream of the core, the flow begins to develop into the distinctive gaussian-type shape we call as jet

3. Equipment's

1. Settling chamber
2. Compressor to compress air
3. Storage tanks for compressed air
4. NI data aquisition card
5. L-shape pitote probe
6. Digital differential manometer
7. Computer

4. Procedure

1. Draw the schematic sketch of the jet flow system.
2. Measure the centerline velocity in the jet at several $\frac{x}{D}$ locations.
3. Measure the velocity profiles of a jet at $\frac{x}{D} = 2, 8$ and 23 .
4. From the acquired data, compute jet width at the two locations.
5. Compare the theoretical incompressible jet results with experimental results.

5. Experimental Setup

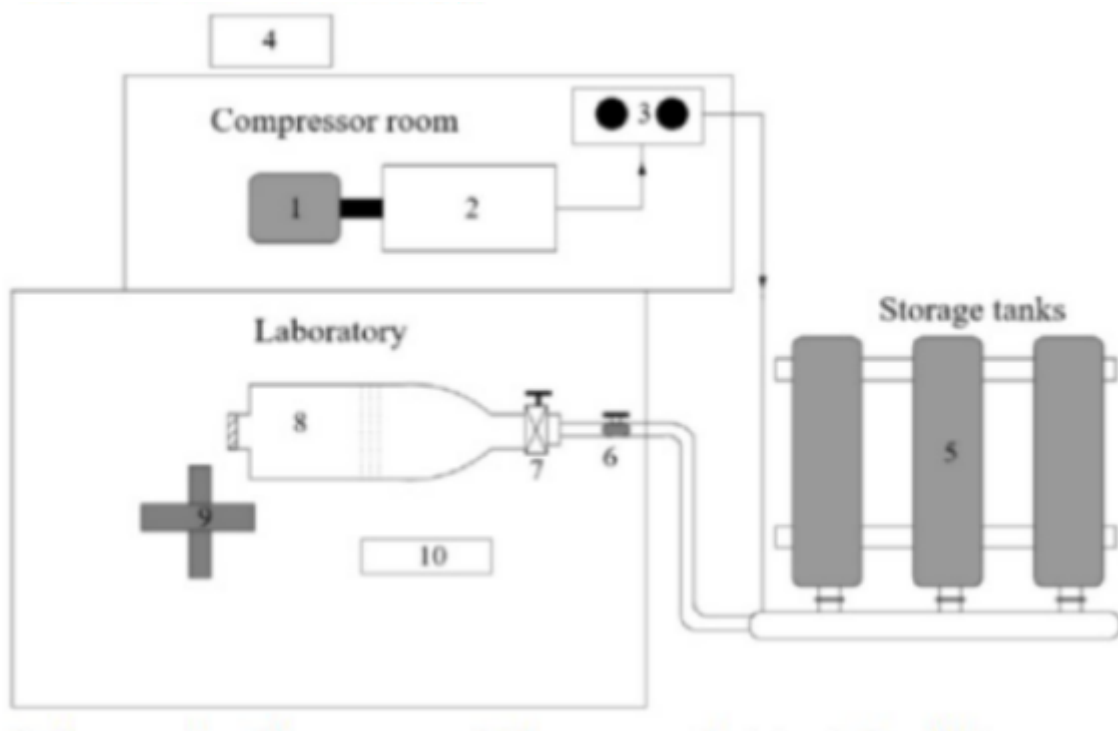


Figure 2. Schematic diagram of open jet facility

1. 150 hp induction motor
2. Reciprocating compressors
3. Activated charcoal filter and silica gel dryer units
4. Water cooling units
5. Storage tanks
6. Gate valves
7. Pressure regulating valve
8. Settling chamber
9. Traversing chamber
10. Instrumentation desk

6. Calculation

Ambient pressure $P_a = 1\text{atm} = 29.921\text{ in-hg} = 101325.027\text{ Pa}$

Ambient temprature $T_a = 303\text{ K}$ (assumed)

$R = 287\text{ J/Kg/K}$, $\gamma = 1.4$ (for air)

Speed of sound $a = \sqrt{\gamma * R * T_a} = \sqrt{1.4 * 287 * 303} = 348.92033\text{ m/s}$

Density $\rho = \frac{P_a}{R*T} = \frac{101325.027}{287*303} = 1.165\text{ kg/m}^3$

Nozzle diameter $D = 10\text{ mm}$

At $\frac{x}{D} = 10.1852$

Stagnation pressure $P_0 = 2.982\text{ in-hg} + P_a = 111423.243\text{ Pa}$

$$\frac{P_0}{P_a} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}} \Rightarrow U_0 = \sqrt{\left[\left(\frac{P_0}{P_a}\right)^{\frac{\gamma}{\gamma - 1}} - 1\right] \frac{2}{\gamma - 1}} = 129.42 \frac{m}{s} \quad (1)$$

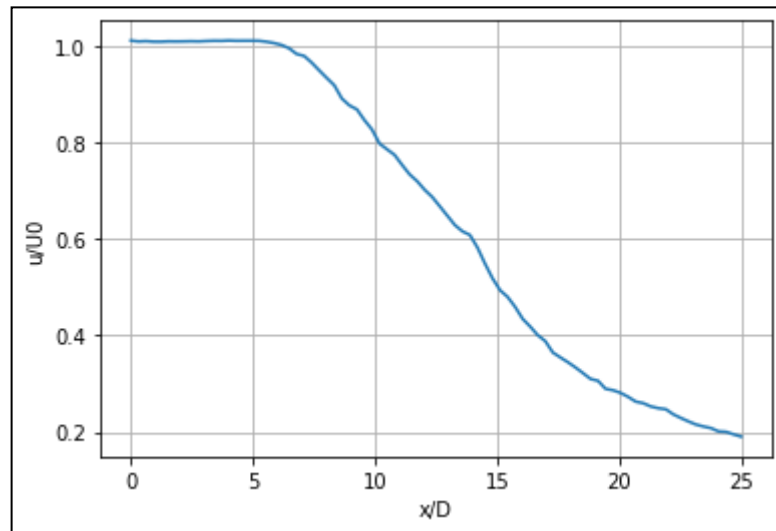
Pitote probe pressure $P = 1.779\text{ in-hg} = 6024.3878\text{ Pa}$

from Bernoulli's equation : $\frac{1}{2} \rho u^2 = P$

$$u = \sqrt{\frac{2P}{\rho}} = 101.689 \frac{m}{s} \quad (2)$$
$$\frac{u}{U_0} = 0.79757235 \frac{m}{s}$$

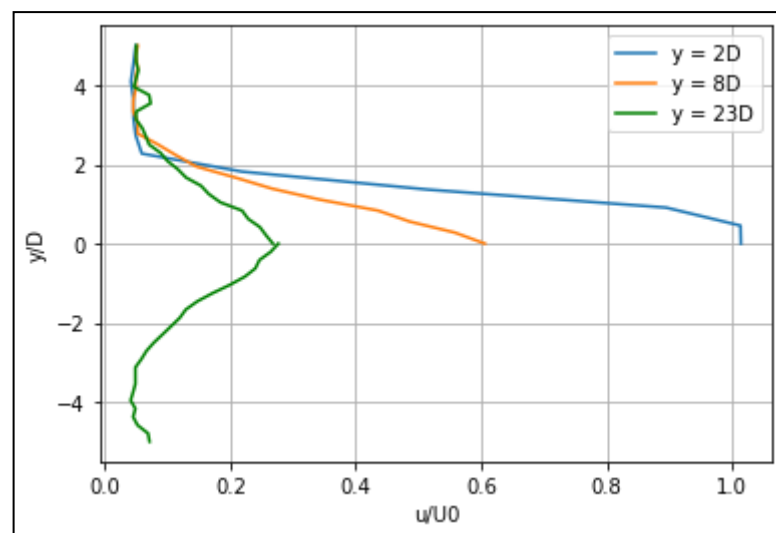
7. Data analysis

Velocity profile for centerline



Graph 1. centerline velocity profile

Velocity profile at different transverse locations



Graph 2. radial direction velocity profile

8. Results

Jet Width

1. at 2D location =
2. at 8D location =
3. at 23D location =

9. Questions

1. What is invariant across a jet?

Ans. Static pressure and linear momentum remain same across the jet.

2. Give two practical applications for jet mixing.

Ans. Water jet cutting and Noise reduction

3. What is jet width? How is it calculated from the velocity profile?

Ans. Jet width at a particular x is defined as twice the distance measured from the centreline to the point on y -axis where the local velocity is half that of centre line velocity at that x .